# METHOD OF MAKING A FRANGIBLE NON-TOXIC PROJECTILE

## BACKGROUND OF THE INVENTION

Cross-reference to Related Application:

[0001] This application claims priority to Provisional Application Serial No. 60/403,655, filed August 16, 2002, the disclosure of which is incorporated by reference.

Field of Invention:

[0002] This invention relates to the field of projectiles for firearms and, in particular, to the field of frangible, non-toxic projectiles for firearms.

Description of the Related Art:

[0003] One measure of the ability of a projectile to penetrate or stop an object may be its kinetic energy. The higher a projectile's kinetic energy, the greater the ability of the projectile to penetrate or stop an object. Kinetic energy (KE) is proportional to one-half of the product of the mass of a projectile and the square of its velocity, or $KE = \frac{1}{2}mv^2$. The kinetic energy of a projectile may thus be maximized by raising its velocity or its mass, or both.

[0004] Since kinetic energy is proportional to the square of a projectile's velocity, velocity may be a logical first parameter upon which to focus. The velocity of a projectile, however, is largely a function of the firearm from which it is fired, and is largely independent of the projectile itself. This leaves the projectile's mass as the only easily variable parameter.

[0005] The mass of a projectile is a product of the projectile's volume and the

density of the material from which it is made. The volume of a projectile is limited by the length of the chamber and the caliber of the firearm, which leaves the projectile's density. The kinetic energy of a projectile may therefore be maximized by maximizing its density.

[0006] Lead is often chosen as a material from which to form projectiles because it is relatively dense. Lead, furthermore, is soft and deforms easily. The deformability of lead may result in expansion of the projectile on impact, so-called "mushrooming". Mushrooming enhances the stopping power of projectiles. Other dense materials that may be used to make projectiles are tungsten and depleted uranium. Tungsten is relatively expensive, however, and both lead and depleted uranium may be toxic.

[0007] Projectiles are often jacketed or coated with an outer layer of copper or other material to protect the barrel from damage or fouling. Jacketed projectiles can be made in "soft point" or "hollow point" configurations to facilitate "mushrooming" of the projectile and maximizing its stopping power.

[0008] Conventional projectiles often remain in one piece upon striking a hard surface. Sometimes conventional projectiles penetrate hard objects or ricochet upon striking a hard surface, even if they deform. Projectiles that ricochet are undesirable for use by law enforcement officers because they increase the risk that innocent by-standers might be injured or killed. Additionally, ricocheting projectiles or projectiles which penetrate hard objects are undesirable for use by security personnel at nuclear facilities, in airplanes, or other sensitive areas, due to the risk of collateral damage. [0009] Indoor shooting ranges may have steel backstops. A steel backstop may be expensive. Projectiles that deform rather than fragmenting into small pieces may tend to damage a steel backstop. A steel backstop that has

absorbed multiple impacts in the same area from projectiles that deform rather than fragmenting into small pieces may eventually require replacement.

## SUMMARY OF THE INVENTION

[0010] In a first embodiment, a method of making a frangible, non-toxic projectile is described in which substantially pure bismuth metal is melted, a quantity of the bismuth metal is poured into a mold, the bismuth metal is cooled to form a substantially crystalline or poly-crystalline bismuth core, the core is swaged in a profile die having a bleed hole, and the core is electroplated thereafter. The swaging step may eliminate substantially a surface irregularity. In one embodiment, the bleed hole may have a diameter of about 0.020 inch to about 0.038 inch in diameter.

[0011] In a second embodiment, a projectile is formed of a core of substantially crystalline or poly-crystalline bismuth electroplated with copper or an alloy of copper.

[0012] In a third embodiment, the projectile may be releasably disposed in a cartridge along with a propellant and a primer, in which the primer ignites the propellant upon contact with a firing pin. The cartridge may itself be releasably disposed within a barrel of a firearm.

## BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0013] Figs. 1A through 1N show some steps of a process for making a frangible, non-toxic projectile according to a first embodiment of the invention;

Fig. 2 shows a projectile for a firearm according to an embodiment of the invention;

Fig. 3 shows a cartridge for a firearm according to an embodiment of the

invention;

Fig. 4 shows a firearm for use with an embodiment of the invention;

Fig. 5 shows an unbled core for use with an embodiment of the invention;

Figs. 6A and 6B show a core being bled according to a second embodiment of the invention; and

Fig. 7A shows a projectile shattering according to an embodiment of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0014] Since projectiles are expendable, it would be desirable for a projectile to be made of a relatively inexpensive material.

[0015] Since there may be a risk of environmental damage associated with a projectile that is made of a toxic material, it would be desirable for a projectile to be made of a relatively inexpensive, non-toxic material.

[0016] Since the kinetic energy of a projectile may be maximized for a projectile that is made of a dense material, it would be desirable for a projectile to be made of a relatively inexpensive, non-toxic, and dense material.

[0017] Since there may be a risk of collateral damage associated with a projectile that ricochets, it would be desirable for a projectile to be made of a relatively inexpensive, non-toxic, dense and frangible material. A frangible projectile may break up upon impact with a hard surface, thus reducing or eliminating the risk that the projectile will ricochet off a hard surface or penetrate too deeply.

[0018] Since it would be desirable for a projectile to be made of a relatively inexpensive, non-toxic, dense and frangible material, it would be desirable for a projectile to be made of substantially pure bismuth. It would further be desirable for

a substantially pure bismuth core to contain no more than trace amounts of naturally-occurring elements, which may be toxic. It would further be desirable for a substantially pure bismuth core to contain less than about 100 ppm of impurities, which also may be toxic. It would further be desirable for a substantially pure bismuth core to contain essentially no naturally-occurring trace elements besides bismuth.

**[0019]** Molten bismuth may be poured in a mold to form a projectile or a projectile core. Molten bismuth, however, may tend to be relatively liquid and water-like, and of a thin consistency. When molten bismuth is poured into a mold, the molten bismuth may have a tendency to splash. Molten bismuth may trap air between the molten bismuth and a surface of the mold if it splashes.

**[0020]** Trapped air may produce one or more creases or folds in the solidified core. A fold may produce a noticeable defect in the surface of the plating, requiring that the projectile be scrapped. Furthermore, a fold that occurs near the heel of a projectile may degrade projectile accuracy. Finally, moisture may be trapped in a fold.

**[0021]** Trapped moisture may be converted to steam while the core is being electroplated or heat-dried. The steam may escape, rupturing the plating. The steam may also weaken the electrolytic bond between the core and the plating. The steam may cause discoloration of the plating. It would be desirable if the size or the incidence of folds or creases could be reduced or eliminated before a core is electroplated.

**[0022]** A core may be swaged in a profile or bleed die to size a core before electroplating. If the pressure required to swage the core is high enough, it may

close folds left on the surface of the core.

**[0023]** A bleed hole may be located in the side of the bleed die. Some of the bismuth may bleed off, i.e. extrude out through the bleed hole while a core is being swaged, thus reducing the size and weight of the core. Since a portion of the bismuth core may be extruded through the bleed hole during the swaging process, the pressure required to swage or fully form the core may be related to the force required to extrude bismuth through the bleed hole. In particular, the pressure required to swage the core may be related to the smallest diameter, the smallest area, or the surface resistance of the bleed hole.

**[0024]** A profile die may be made of a relatively hard material such as tungsten-carbide. A bleed hole of a small diameter may be difficult to drill in a hard material. A standard size bleed hole of the type used in the industry to bleed a lead or lead-antimony bullet core may have a diameter of about 0.050 inch to about 0.062 inch. A bleed hole of this diameter however, may not allow much in-die pressure to develop, especially when attempting to bleed core materials that are harder than lead or lead alloy. If bismuth is being extruded it may extrude too easily for a significant amount of in-die pressure to develop. In particular, the pressure may be insufficient to cause the folds to close up completely. In effect, the core may be bled to weight before the bismuth lying near the exterior surface can be rearranged materially.

**[0025]** It would therefore be desirable if a core could be bled more slowly, allowing higher pressures to develop and giving the folds near the surface of the core time to close. It would further be desirable if a bleed hole of smaller diameter could be formed in the profile die to offer more resistance to the extruded bismuth, allowing

higher pressures to develop and slowing the bleeding process down to give the folds near the surface of the core time to close.

**[0026]** A bismuth core may be inserted into a metal jacket. A jacket may be made of copper or a copper alloy, such as an alloy of 95% copper and 5% zinc. A copper alloy jacket, however, may tend to flatten rather than breaking up on impact. Such a jacket may be too thick or tough to fragment into small pieces. Furthermore, since copper and its alloys may be malleable, it may protect the bismuth core from breaking up as well. It would be desirable for a copper or copper alloy jacket to break up on impact, along with the bismuth core.

**[0027]** Furthermore, electroplating may have certain advantages over a conventional projectile jacket when combined with pure bismuth, such as an ability to fill in the flats and angles on the surface of crystalline or poly-crystalline bismuth. This may make a projectile produced by pouring a pure bismuth core and electroplating it more balanced, and therefore more accurate, than a projectile made by inserting bismuth into a jacket. It would be desirable for a coating to be electroplated on a bismuth core.

**[0028]** Furthermore, the chemical bond formed between the cladding and the bismuth core by electroplating may produce a more frangible projectile than a conventional jacketed projectile, since a conventional projectile jacket may have a propensity to flatten on impact instead of breaking apart. A flattening jacket may thus impede fragmentation of the core. A chemical bond between an electroplated coating and a bismuth core, on the other hand, may be strong enough to break the coating up into small pieces at the same time the core breaks up when the projectile strikes an object, such as a steel backstop. It would thus be desirable for a coating

to be electroplated on a bismuth core.

[0029] In Fig. 1 is shown a process for making a frangible, non-toxic projectile according to a first embodiment of the invention. As shown in Fig. 1A, substantially pure bismuth metal may be heated to a temperature above its melting temperature (271.3° C, 520.3° F) until it melts. As shown in Fig. 1B, a quantity of the molten bismuth may be poured into a mold 122, which may have a cavity 124 of generally ogival shape. In alternative embodiments, cavity 124 may have a spherical, oblong, ovoid, cylindrical, conical, frustoconical or ellipsoid shape. In one embodiment, a fold 152 may form in a surface of core 118, as shown in Fig. 5.

[0030] As the quantity of bismuth cools it solidifies to form a core 118, as shown in Fig. 1C. If mold 122 is not disturbed unduly while the bismuth cools, a single crystal of bismuth may be formed. In the alternative, polycrystalline bismuth may be formed.

[0031] As shown in Fig. 1D, the solidified bismuth core 118 may be inserted in a profile die 126 which may also have a profile of generally ogival shape. Profile die 126 may have a bleed hole 128. There may be more than one bleed hole 128. Bismuth core 118 may be swaged in profile die 126 using pressure sufficient to force bismuth core 118 to assume the shape of profile die 126. Some of the bismuth may bleed off while bismuth core 118 is being swaged. In one embodiment, about three to about twelve grains of bismuth metal may be bled off. The bismuth extruded through bleed hole 128 may form a bleed wire 129. Bleed wire 129 may be removed from core 118. In one embodiment, bleed wire 129 is removed by shearing it off core 118.

[0032] In one embodiment, bleed hole 128 may be formed in profile die 126 with

an electronic discharge machine (EDM). An EDM may form a bleed hole 128 of 0.020 inch diameter. A bleed hole 128 of about 0.020 inch diameter internal may increase the die pressure developed during swaging and close or eliminate fold 152 in the surface of the bismuth core. In alternative embodiments, a diameter of the bleed hole may vary between about 0.020 inch and about 0.032 inch. In one embodiment, the diameter of the bleed hole depends on the size of the core. In one embodiment, bismuth core 118 may be rearranged sufficiently during the swaging process to close fold 152.

**[0033]** As shown in Figs. 1E and 1F, bismuth core 118 may be prepared for electroplating by cleaning it in a detergent bath 144 to remove contaminants and surface residue. A clean surface may be important for effective electroplating. Detergent residue left from the cleaning process may then be rinsed off.

**[0034]** As shown in Figs. 1G through 1J, bismuth core 118 may then be placed in an acid activation tank 146, rinsed, and immersed in a cyanide strike bath 148. Bismuth core 118 may then be rinsed further and immersed in an acid-copper bath 132. Bismuth core 118 may be connected to a cathode 134 of a voltage source, and a voltage may be applied across the acid-copper bath 132 by immersing a corresponding anode 136 in the bath 132 for a period of between about seven and about fourteen hours.

**[0035]** The electroplating process may proceed until bismuth core 118 is substantially completely covered with a coating 120 of copper, forming a projectile 114. In alternative embodiments, bismuth core 118 may be substantially completely covered with a coating 120 of brass, german silver, tin, bronze, or aluminum. The cathode 134 and the anode 136 may be reversed in the case of some coatings 120,

depending on the electrical potential of the coating 120 relative to that of the bismuth. In an alternative embodiment, such as in the case of an aluminum coating, core 118 may be anodized.

[0036] Coating 120 may have a thickness between about 0.005 inch and about 0.008 inch per side. As shown in Figs. 1K and 1L, a tarnish inhibitor 154 may be applied to the projectile 114, after which it may be dried in a dryer 156.

[0037] As shown in Figs. 1M and 1N, projectile 114 may be swaged in a second profile die 138 to force it to assume a desired final shape and size, after which it may be tumble-polished in a barrel 150 containing polishing media 151. Projectile 114 may then be inspected and packaged.

[0038] In Fig. 6A is shown a core 218 being bled in a profile die 226 according to a second embodiment of the invention. Profile die 226 has a bleed hole 228 through which a bleed wire 229 may be extruded. In Fig. 6B a knockout punch 230 is shown ejecting core 218 after it has been bled.

[0039] In Fig. 2 is shown a projectile 114 for a firearm according to a second embodiment of the invention. A core 118 of projectile 114 may be formed of substantially pure crystalline or poly-crystalline bismuth. In one embodiment, core 118 of projectile 114 may be brittle or frangible and break apart or shatter upon impacting a hard or rigid surface. When core 118 shatters, as shown in Fig. 7, its kinetic energy may be distributed among individual particles 121. Individual particles 121 may possess low individual energies. A tendency of individual particles 121 to ricochet may consequently be reduced. An ability of individual particles 121 to penetrate objects with unintended consequences may also be reduced.

[0040] In a preferred embodiment, core 118 may be gravity cast. If core 118 is

gravity cast, molten bismuth may be poured into a mold that may have the same basic shape or profile as the final projectile. In alternative embodiments, core 118 may be sand cast, permanent mold cast, die cast, investment cast, or cast by a lost wax or lost foam process.

**[0041]** Core 118 may be electroplated with a coating 120 such as copper, a copper alloy such as brass, bronze, german silver, or aluminum. In a preferred embodiment, coating 120 may be about 0.007 inch thick.

**[0042]** In one embodiment, core 118 may be slightly longer than projectile 114. Core 118 may be slightly longer than projectile 114 because it is still in "unbled" condition as it comes out of the mold. Bleeding the core to final weight may decrease the length so that it is several thousandths of an inch shorter than projectile 114.

**[0043]** In one embodiment, core 118 may be approximately 0.014 inch shorter than projectile 114. In one embodiment, core 118 may be slightly narrower than projectile 114. Core 118 may be slightly narrower than projectile 114 because it lacks the thickness provided by coating 120.

**[0044]** In Fig. 3 is shown a cartridge 100 for a firearm according to a third embodiment of the invention. Cartridge 100 may include a casing 102 which may be made of an alloy of copper, such as brass. An explosive propellant 104 in the form of a powder may be contained within casing 102. Casing 102 may further have a primer 108 at a rear end 110 to ignite propellant 104. Primer 108 may be actuated by a firing pin 112 of the firearm. Projectile 114 may be held within neck 116 of casing 102, a core of which may be formed of substantially pure crystalline or poly-crystalline bismuth. Projectile 114 may be expelled from casing 102 by propellant

104.

**[0045]** In Fig. 4 is shown a firearm 140 for use with an embodiment of the invention. Cartridge 100 may be insertably disposed within a barrel 142 of firearm 140. Projectile 114 may be used in a pistol or a rifle of .22 caliber to .50 caliber, as a slug in a shotgun of 10, 12, 16, or 20 gauge, or .410 caliber, or in a cannon of up to about 16 inch diameter.

**[0046]** While the invention has been described in detail above, the invention is not intended to be limited to the specific embodiments as described. It is evident that those skilled in the art may now make numerous uses and modifications of and departures from the specific embodiments described herein without departing from the inventive concepts.